the Mechelecty

Volume 23 May - 1965 No. 6

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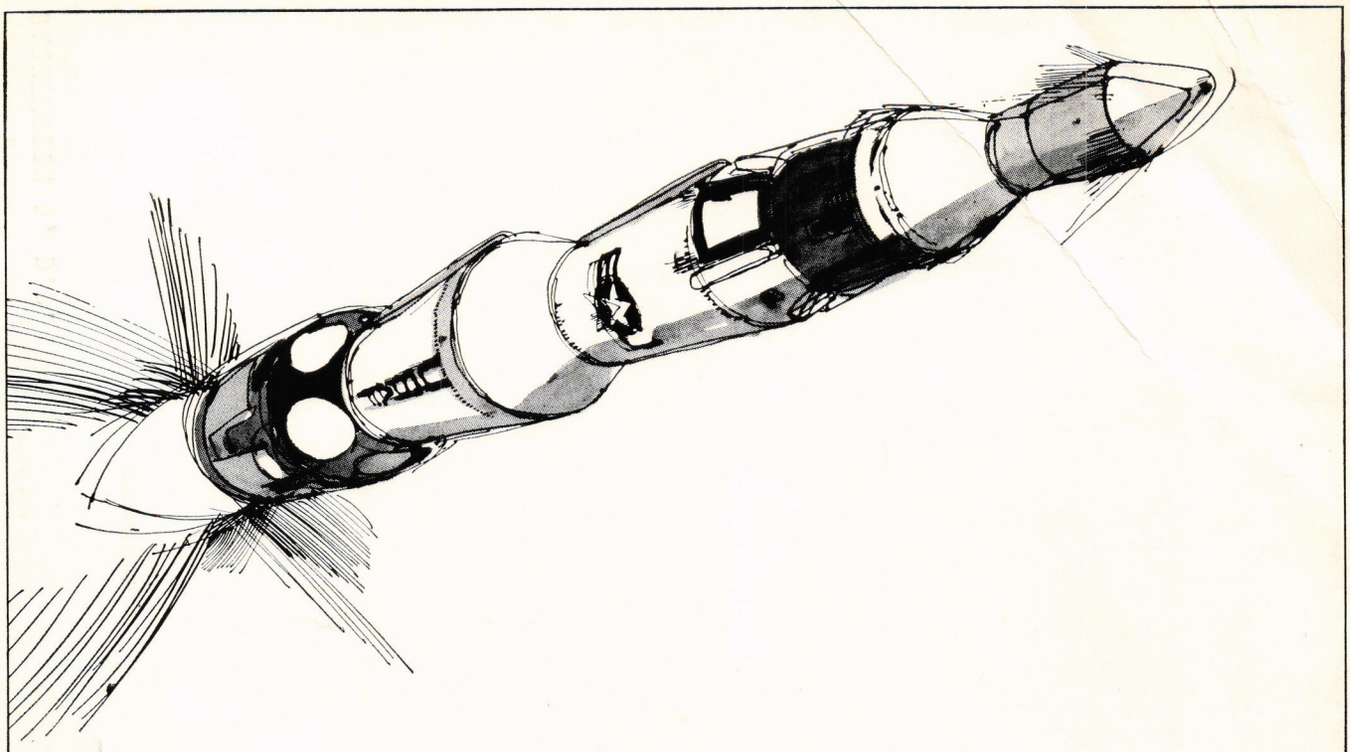
MAY 1965



College graduates do key work right away on the Aerospace Team.
Lt. Gregory Risch, aeronautical engineer from Notre Dame, varsity swimmer, missile test expert, tells how you can be part of it.

(Lt. Risch, B.S. '62, did extensive undergraduate work in aerodynamics, helping to construct one of the country's largest and most successful smoke tunnels. He has played an important part in the operations of the test range at Cape Kennedy.)

What's the best way to become an Air Force officer?

I wouldn't want to call any one way the "best" way. We count on getting top-quality officers from all our sources. First, there's the Air Force Academy. I received my commission through Air Force ROTC. Many colleges and universities will soon be providing two-year AFROTC programs that you can apply for during your sophomore year. Then, for the college graduate, there's Air Force Officer Training School—OTS.

Who's eligible for Air Force OTS?

Any college graduate, male or female, or a college student within 210 days of graduation, is eligible to apply. Who the Air Force will take depends on what the particular needs are at the time. Those with scientific or engineering degrees can usually count on receiving the first openings.

Does the Air Force have jobs for nonscience majors?

There are quite a few jobs in nontechnical fields such as administration and personnel. And it is not essential that prospective pilots or navigators have backgrounds in the sciences. However, since the Air Force is one of the world's leading technological organizations, a keen regard for science is important.

What sort of work do young Air Force officers do?

Important work. An Air Force career gives young people the opportunity to do meaningful work right from the start. That's the thing I like best about it. I'm only a couple of years out of college, but already I'm working on a vital project in an area that really interests me. In other words, I'm getting to *use* the things I studied in college. My education is paying off, both for me and for the United States.

What are the possibilities for advancement?

They're plenty good. The Air Force believes in giving its young officers all the responsibility they can handle. That's not only good for you, it's good for the Air Force. It gets the best-qualified people into the top jobs where they can contribute most to our defense effort.

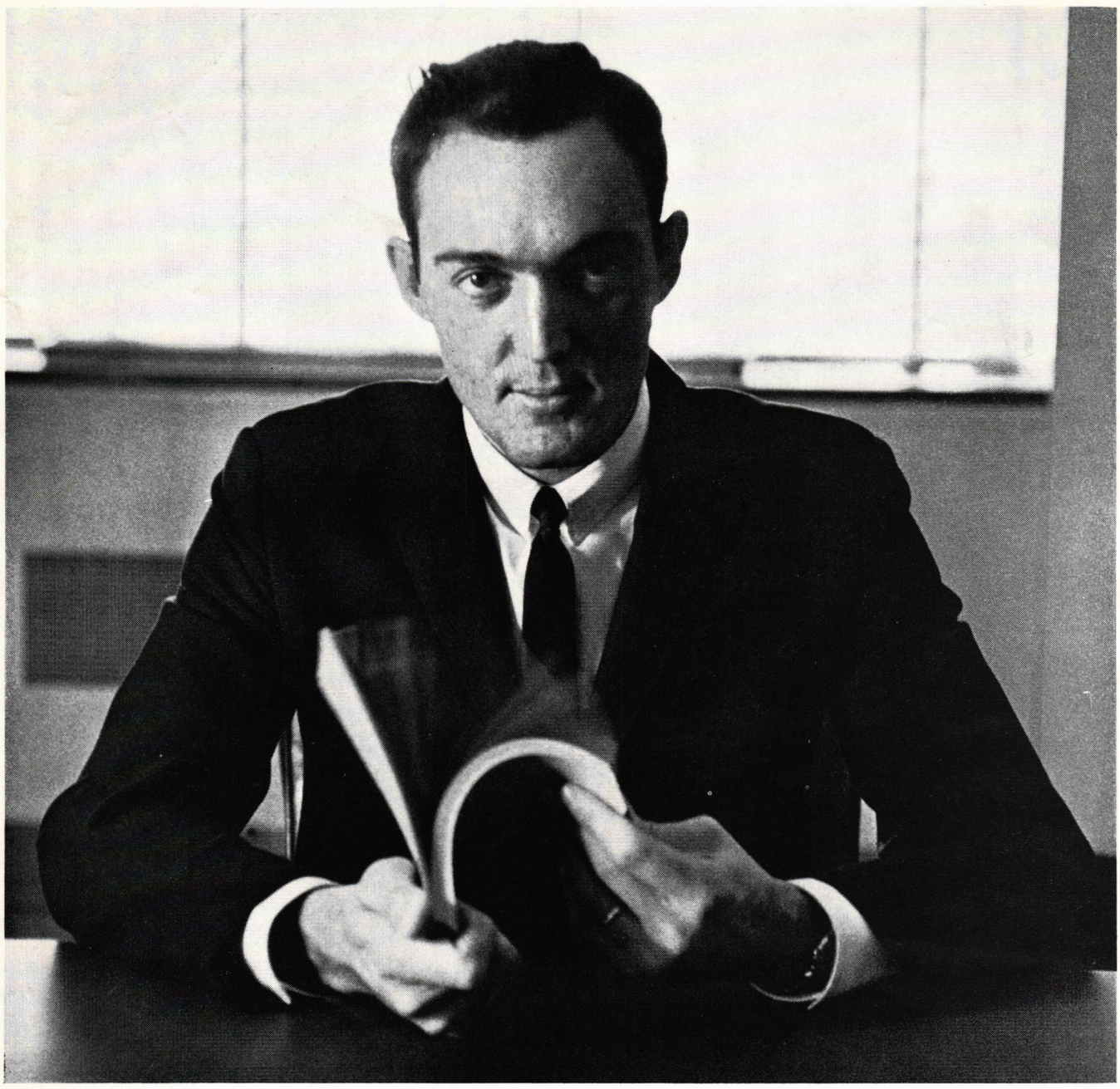
How long am I committed to serve?

Four years from the time you receive your commission. If you go on to flight school, four years from the time you're awarded your pilot or navigator wings.

Where can I find out more?

If there's an Air Force ROTC unit on your campus, see the Professor of Aerospace Studies. If not, contact the nearest Air Force recruiting office. It's listed in the white pages of the telephone book under "U.S. Government".

United States Air Force.



How about a friendly game of cards?

Watch out for our Gene Wollaston, though. He stacks the deck. In fact, he's already stacked 80 decks—of computer cards—to build a mathematical model to solve important refinery problems. With his special skills, Dr. Wollaston helps determine proper product yields and properties from key refinery operations. The final result should be an improved product—at a tremendous saving of time and money. (Once the model is built, the cost of solving a problem is as little as $3.00.)

So, as a card player, Gene's helping to take the gamble out of running a refinery. No mean accomplishment for a chemical engineer two years out of Illinois Institute of Technology.

You're not a card player? Don't worry. As long as you're looking for a meaningful challenge, your opportunity may be here at American Oil. We're also experimenting with fuel cells, spatial environment, and rust protection in car engines—to mention a few of our diverse fields of interest. Some of them may interest you, whether you're in Engineering, Physics, Chemistry, Mathematics, or Metallurgy.

You can find out by writing for more information. To J. H. Strange, American Oil Company, P. O. Box 431, Whiting, Indiana.

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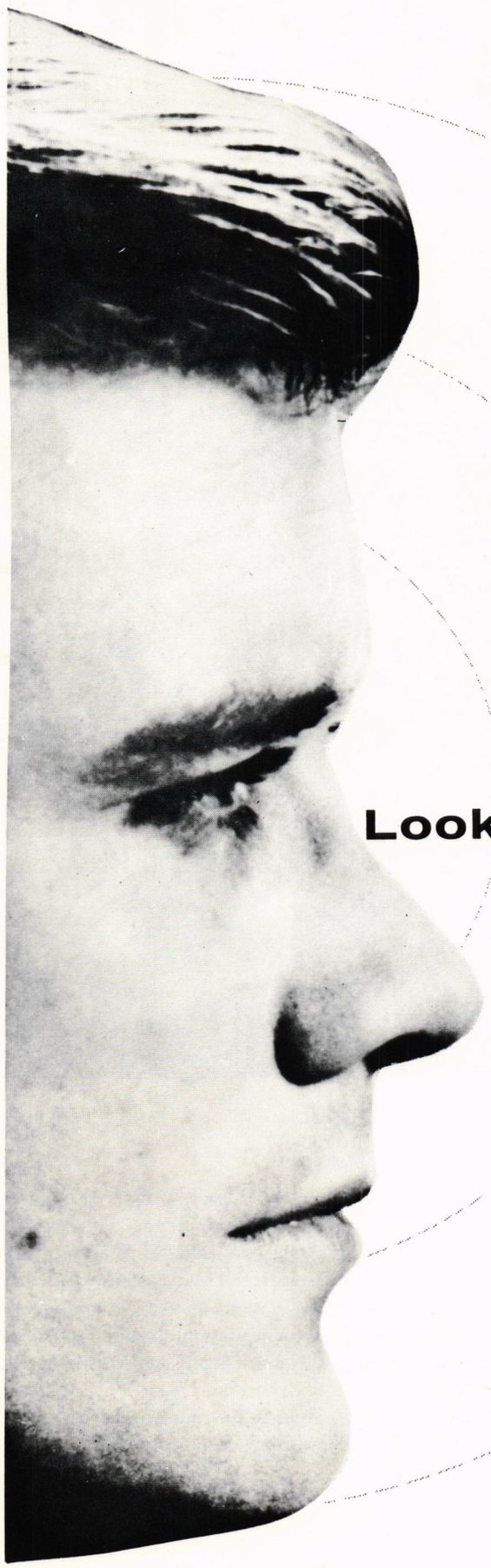

First, what is the obvious? It's obvious that you're in demand. You don't have to worry about getting your material wants satisfied. And you don't have to worry about getting opportunities for professional growth.

But, if you look beyond the obvious, you'll realize now that you're going to want something more than material rewards from your career. You're going to want **pride**—pride in your personal, individual contribution.

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The Mechelecіv

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COVER

It looks like our Friendly Little Indian made it, at least he has his cap on straight . . . Now all he has to do is apply all that behind him.

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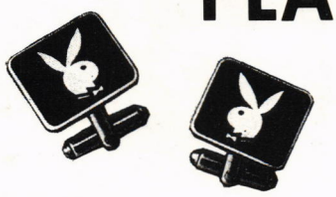
The PLAYBOY ENGINEER'S *Philosophy*



In the last two editorials of this magazine, we have filled four pages with thoughts on the "best" way for a young engineer to live his life. We did this by describing "the playboy engineer," a man whose personality combines the fun-loving attitude of the playboy and hard-working attribute of the professional engineer.

The reaction to these two editorials seems, for the most part, to have been favorable. There was not, however, very much written response. As a matter of fact, we received only one letter. It is far from favorable, but it is a sincere letter and worth our consideration. So what we will do in this editorial, our last, is to print that letter and then try to defend or amend our philosophy accordingly. Here it is:

"Dear Sir:

Your editorial of the March issue of Mecheleciv deserves a few lines of comment. I have been a practicing engineer since I graduated from George Washington in 1957 and find your article rather frightening. One of the things the engineering profession does not need is "playboys." It does need however, serious, mature individuals who consider their jobs important to themselves and to their profession. Whether he is in research, sales, design or production, he knows that he cannot contribute to the profession unless he has one very important factor: maturity. Maturity leads the research and design engineer to graduate school. We all wonder why people do not consider engineering a profession. When we start acting like men instead of "playboys" maybe we will get the professional recognition that we all desire.

Yours truly,

John Barranger
Strongsville, Ohio

From reading this letter, it is clear that Mr. Barranger's conception of a "playboy" is unfortunately based on the popular, but stereotyped definition: a rich, but lazy spendthrift whose only concern is with beautiful women and sport cars. We regret very much that the word "playboy" has acquired this negative meaning, and we attempted to re-define the word in the March editorial. (Perhaps what we should have done is used a different word altogether.) In that editorial, we adopted Hugh Hefner's definition of the playboy: the type of man who believes life should be a "happy time," who takes "joy in his work, without regarding it as an end and all of living," and who is "alert" and "sensitive to pleasure."

When this type of man also happens to be a professional engineer, he becomes what is for us an ideal engineer -- a playboy engineer. We certainly wanted him to be a serious and mature individual, but we did not want him to ever become too serious or too mature.

When the engineer takes his work too seriously, his life tends to become unbalanced, and both he and the people around him suffer as a result of it. So our playboy engineer works and plays to the hilt. He works to three in the morning on an engineering job that is "important to himself and his profession." But he also plays till three in the morning when the discussion turns to philosophy or when the girl feels the same way as he about "senseless inhibitions." Sometimes, he sleeps all night.

What about maturity? This is a word that has many meanings. When it means "fully developed, complete, wise, or responsible," we would want the word to apply to our playboy engineer. But maturity is also used to describe the battle-scarred adult who has lost his sensitivity, his curiosity, and his enthusiasm for living. In this sense, the playboy engineer will never be mature. Out with a lovely "playmate" on a moonlit night, he can put away his scientific objectivity and allow himself to be fully sensitive to the depth of human emotion. The playboy engineer can look upon the electromagnetic wave theory as an answer to his "childish" curiosity about sunlight as well as an answer to his antenna problem. And he never forgets how to look at a turbine engine or a digital computer through the enthusiastic eyes of a boy. Just as he hates to lose his perspective by becoming too serious, he also hates to throw out all the good things of his boyhood days by becoming too mature.

So now we ask, is the engineering profession hurt by having playboys -- of the responsible, well-balanced type -- in its ranks? We don't think so. For when the engineering profession includes playboy engineers, it includes men who lead human lives, and thus men who can balance both the technical and human aspects of their work. If engineering has a "black-eye" today, it probably is because engineers are guilty of ignoring people as human beings. We strongly feel that what the engineering profession does need is more "playboy" engineers.

LETTER TO THE GRADUATES

From DEAN MARTIN A. MASON

In a few weeks, in this School and about two hundred others in the United States, many young men and some women will become graduate engineers. They will then begin their professional careers in a world dominated by technology. As engineers prepared by their schools to become productive servants of humanity they occupy a specia! place of opportunity and responsibility.

You who are about to enter this place must recognize that you are joining a very select group, on whom the rest of mankind depends for its safety and comfort. That dependence requires you to undertake certain responsibilities.

To do so you must appreciate your position in the hierarchy of humanity. It may be stated simply -- you are the "doers" for mankind. Some of you may become of the dreamers who see ahead and set the directions others will explore; others of you may become the explorers of new paths and mayhap some will find as life unfolds that their talents lead them to unsuspected endeavors. Probably the majority can anticipate their efforts to be in the development of ideas and their conversion into the useful technology on which our civilization depends.

The pace of mankind toward its ultimate state is quickening. More people are now alive than ever before; our growth is so rapid that in many areas of the world there is neither space nor food to support the existing population, much less the accelerating millions of their descendants. We are now facing problems of a complexity and importance never before confronting man -- and the problems ahead are more numerous and complex.

Technology alone offers the promise for solution of the problems, for survival for today's humanity, and a future for their progeny. This promise cannot be matched by those of ideologies, or politico-economic systems, or humanism, or nationalist jingoisms. While humanity has failed consistently to solve the problems of man, technology has progressed quietly and steadily to provide the material needs that sustain man. While man has striven unsuccessfully to resolve the problems between governments, technology has been satisfying the needs and desires of governments in their struggles for power and position.

One has only to make a rational appraisal to realize that, in fact, man's progress has been chiefly technological. We may well ask ourselves -- will the technologist, the engineer, who has demonstrated consistently and over and over his ability and dedication to the improvement of man, be the prime mechanism through which man may reach his ultimate state?

I believe the signs are clear that engineers and technology are now playing a controlling but largely unrecognized role in man's development, and that they will do so increasingly. With that role there is associated a special responsibility -- that of serving mankind as a whole, in addition to the familiar responsibility of serving the individual and his particular society which engineers have discharged so well to now. It is not hard for me to conceive that within possibly a decade engineers may have to choose between continuing to help to advance the mad race of man against man and nation against nation, or consecrating their efforts to the unity of mankind and its vital competition against nature.

Therefore, I believe you should pursue and cultivate the knowledge and wisdom required to fulfill your place. You must have much more than the technical competence your School has helped you to achieve. The development of a discriminating social consciousness, and political sophistication, and a personal sense of ethic in a society giving many indications of absence of ethic, is a responsibility you must accept as you enter this special place of engineers among mankind.

You must help the humanist, who fails to perceive the futility of his actions despite the merit of some of his concepts; you must influence the politician to fight for mankind as well as his district; and you must encourage the butcher, the baker, and the candlestick maker to recognize that your satisfaction of their material needs imposes on them responsibility to live together better than they have to mankind's benefit.

Your task is to provide the means to security and comfort for all of man, and through your wisdom and concern for humanity to help lead man to his ultimate destiny. Godspeed to each of you as you undertake your task.

PULSE FREQUENCY MODULATION

by John Wolfgang

Telemetry implies the measurement of a quantity from a location removed from the site of the event. The telemetry transmission link may be via light, sound or electromagnetic radio waves. In any of these modes of transmission, attenuation of the data signal is a serious factor. Inherent with this attenuation, interference in many forms is usually present, which perturbs the signal information causing misinterpretation errors by the receiver. In order to minimize the effects of the various undesirable perturbations, encoding of the data at the source is required. The maximum immunization to noise is governed by Shannon's channel capacity theorem relating the minimum data recovery error to data bandwidth, noise power and signal power (reference 1). Basically the problem then is to utilize a system which approaches the maximum transmission link capacity and which allows a reduction in transmitter power.

Since it is usually both undesirable and impractical to send data from each signal source over an independent transmission link, the process of multiplexing is used. Multiplexing is the sending of more than one source (or channel) of information over a single link. This intermixing process may be performed either in frequency or time. In frequency division multiplexing each channel of information is assigned its own band of frequencies (or subcarrier) and the linearly added subcarriers then modulate the transmitted carrier. The resulting modulation is known as FM-FM, FM-AM or FM-PM, where the last two letters in the modulation nomenclature denote the modulation technique: e.g., FM is frequency modulation, AM is amplitude modulation and PM is phase modulation.

Frequency division multiplexed telemetry is standardly used with frequency modulation to gain the inherent signal to noise improvement this technique offers over amplitude modulation. However frequency modulation has several disadvantages: first, the signal to noise ratio is only improved with wide carrier deviations (i.e., wide transmission bandwidth) and secondly, the well-known sharp thresholding phenomenon at low signal levels. FM-FM in itself has another disadvantage in that guard bands of frequency, in which no data is allowed, must exist between the subcarrier frequency bands in order to allow reliable recovery and deciphering of the data on the receiving end.

The second division of data transmission is time-division multiplexing. Time-division multiplexing is the sequential and periodic sampling (commutation) of a number of sources of data and the assembling of these samples into a serial data train. Each source is periodically assigned a finite time for transmission. Examples of time-division multiplexing are the various pulsed telemetry systems.

Developments in pulse modulation and pulse coded modulation lagged frequency modulation. Early work in this field led to pulse amplitude modulation-PAM; pulse position modulation-PPM; and pulse duration modulation-PDM. Needless to say any of these systems could use amplitude modulation, phase modulation, or frequency modulation as the transmission scheme. These systems however rely on the precise determination of pulse amplitude, position or duration, all of which are quantities hard to resolve in the presence of noise.

In the late 40's and early 50's, Shannon and Hamming performed studies which predicted that pulse coding would have error reducing properties and which produced practical schemes of coding to effect these properties (reference 2). This system is known as pulse code modulation -- PCM.

With the criteria in mind of designing a telemetry system which minimizes the data recovery error and which is efficient and reliable, pulse-frequency-modulation -- PFM -- was developed. Pulse frequency modulation, with the advent of modern semiconductors and magnetic cores, has gained an advantage in low power requirements and long term hardware reliability.

A PFM signal consists of a series of time multiplexed sequential tone bursts of known pulse length. The frequency of the burst conveys the desired data information. Figure 1a shows the pulse pattern (or format) for a typical N.A.S.A. Goddard Space Flight Center PFM signal. If there are N channels (or sources) to be sampled then each channel would be associated with a separate frequency burst and the frequencies of these N bursts would represent the data of the sequentially sampled channels. In practice in the NASA/GSFC PFM system there are 16 channels with the first channel reserved for synchronization. Periodic data bursts must be reserved for synchronization data in order to identify the location of a particular data source in the tone burst train. A set of 16 channels is known as a frame, and 16 frames complete a telemetry sequence. Figure 1b shows a complete telemetry sequence. The tone bursts are transmitted beginning with channel zero – frame zero and progressing in time through frame zero, then to frame one and so forth until a complete sequence has been telemetered. Each channel is divided into two parts. A data channel has equal data and blank times. The blank time is to allow the contiguous filter banks used on the receiving end to recover before the next data burst. This blank time (time of no modulation) is utilized on the ground to determine channel synchronization. Present satellites, notably the Interplanetary Explorer Series (IMP), have a known constant frequency tone burst, outside the data frequency band, in the blank portion of each channel for channel synchronization.

John Wolfgang is attending graduate school part-time while working for NASA at Greenbelt, Maryland. He received his undergraduate degree at GW and was one of the editors of Mecheleciv in 1962.

Channel zero has a 3/4 channel wide burst for frame identification purposes. Every other channel zero has a known reference tone burst (marked sync in figure 1b) identifying the start of the frame. The channel zeros without a reference burst contain one of eight different frequencies representing a particular frame number: e.g., a tone representing octal 000 would mean frame 1. Thus both the start of each frame is marked as well as the number of the frame.

As with any pulse-coded system simplicity in transmission hardware is paid for in the magnitude of synchronization and decommutation equipment required at the processing terminal. With improvement in data synchronization techniques and hardware a greater proportion of the telemetry may be allocated for data transmission. The present state of the art allows the channel blanks, previously used for channel synchronization, to be utilized for data.

In PFM, both analog and digital data may be easily encoded. PCM suffers in that all data must be converted into digital form for transmission. Data signals are encoded in the NASA/GSFC PFM using pulsed oscillators. For analog data a subcarrier oscillator, whose output frequency is directly proportional to the analog voltage impressed at its input, is used. The linearity of the presently used analog oscillator is better than + 1/2 percent over a 3:1 dynamic frequency range. Typically the long-term accuracy of measurement is within 1 percent. However, short-term precision measurements can be made to 1/10 percent (reference 3).

Digital signals are telemetered by combining binary bits and presenting these as a single digit of a higher order base. The present state of the art allows encoding of three bits into one digit to the base eight, or four bits into one digit to the base sixteen. For example in the base eight system one of eight frequencies is transmitted in pulse tone form, representing one of eight octal digital numbers. Similarly in the base sixteen system one of sixteen tone bursts would be transmitted. This is accomplished with a pulse digital subcarrier oscillator, whose output varies with the states of the three (base eight) or four (base sixteen) binary input signals. Any of these oscillators (analog or digital) may be commutated from channel to channel or one oscillator may be used for more than one channel. Since only one oscillator is pulsed at a time, adding additional oscillators does not materially affect the power drain.

The output of the system to the modulator is a square wave. Because of this and the inherent difficulty in employing phase-detection coherently when using frequency modulation, and the poor signal to noise considerations when using amplitude modulation, the rf carrier is phase modulated. Phase modulation has the advantage that

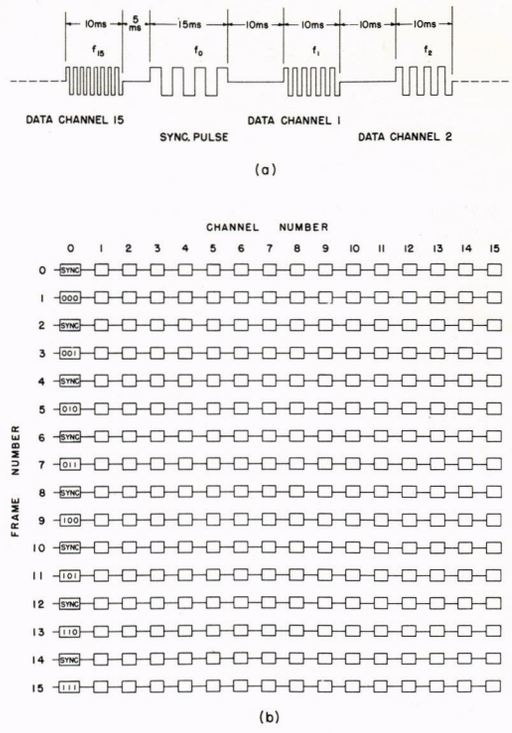


Figure 1. Typical Pulse-Frequency-Modulation a) Frame tone burst pattern b) Sequence Format.

the ratio of sideband power to carrier power may be controlled by changing the peak phase deviation. In order to provide adequate data information, for various satellite orbits, the system bandwidth (frequency range of oscillators), data rate (channel duration in time) and transmitter power are adjusted. For example, the PFM telemetry flown on Explorer XII had 5kc to 15kc oscillators and 10ms burst and blank tone durations. The highly eccentric orbit IMP series Explorer XVIII and Explorer XXI have oscillator frequency range of 200cps to 1kc and 320ms burst and blank tone durations.

Pulse Frequency Modulation was first flown on Vanguard III (1959). Since that time many other satellites have utilized PFM for their telemetry. Explorer VIII (1960), the Ionosphere Direct Measurement Satellite, and Explorer X (1961) which measured the interplanetary field both used PFM. Explorer XII (1961), Explorer XIV (1962) and Explorer XV (1962) which performed continuous measurements of energetic particles in the Van Allen belts all utilized PFM. The Interplanetary Monitoring Platforms, Explorers XVIII and XXI and the joint United Kingdom-United States satellites Ariel I and Ariel II have utilized this low-power lightweight telemetry.

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2. Hamming, R. W., "Error Detecting and Error Correcting Codes," Bell Sys. Tech. J. 29(2): 147-160 April 1950.
3. Rochelle, R. W., "Pulse-Frequency-Modulation Telemetry," NASA Technical Report TR R-189, January 1964.

MECH MISS . . .

The Mecheleciv staff presents Miss Julia Cobb as our final Mech Miss for the year. Julia is a senior majoring in Chemistry which shows that beauty and brains can be very nicely compatible. She has been active in Alpha Delta Pi having served as Treasurer and Social Chairman. To show her diversity of interest, she is also a member of the Judo Club at the university. You just never know what to expect, fellows. Sailing and water skiing are other activities that occupy her time during the warmer months of the year.

For the reader's interest, certain statistics can be obtained by solving the system of equations below (a most interesting application of Cramer's rule):

$$\begin{aligned} 6x - 24y + 14z &= 166 \\ -7x + 15y - 3z &= -13 \\ 13x + 8y - 9z &= 303 \end{aligned}$$

CAMPUS NEWS

by Ken Belford

SIGMA TAU

Two faculty members and ten students of the School of Engineering and Applied Science were honored by initiation into Sigma Tau, national honorary engineering fraternity, on Saturday, April 3, 1965. Professors R. B. Heller and D. K. Anand were elected to honorary membership. New student members initiated were:

Barrington Cox	Telly Manolatos
Thomas Criss	Joseph Martino
Martin Hum	Orville Standifer, Jr.
Aaron Jestice	John Starke
K. Khozeimeh	Paul Teter

In addition, Douglas Lowe was initiated on April 21 at the regular meeting of the fraternity.

by Norman Seidle

THETA TAU

To say that 20 odd students were surprised is a rather gross understatement. At the job interview symposium, held on March 31, these students discovered that potential employers will pay little attention to their grades or even the university from which they have graduated.

The factors which determine whether or not a student will be offered a job are such things as his dignity, his ability to write or more generally his ability to communicate, his extra curricular activities, his knowledge of humanities, etc. In other words, his technical knowledge probably will not be questioned.

This was the unanimous opinion of Mr. Reynolds, Federal Commissioner (Ret.); Mr. Bell, Technical Staff, Melpar Inc.; and Mr. Taylor, Polaris support department, Vitro Corp. at the Theta Tau sponsored "symposium." Each of these men regularly interview and hire engineers.

The OPEN FORUM for 1965-1966

by Scott LeBeau
President, Sigma Tau

The OPEN FORUM, which was initiated by Sigma Tau Fraternity last fall has enjoyed a very successful first year. This program was initially conceived of as a medium for student-faculty discussion; that is, it was intended to provide both students and faculty members with the opportunity to find out how others felt about certain controversial issues directly affecting the Engineering School. To this end Sigma Tau selected various topics for panel discussion and encouraged those who attended to offer any opinions and ask any questions that they might have. This system worked quite well, and was therefore employed in all of the more recent discussions, including those on Teaching Methods, Textbook Selection, the New Curriculum, etc.

Due to the favorable reception of our program, Sigma Tau has decided to continue with it next fall; however, the topic matter emphasis will no longer be placed on narrow subjects of sole interest to engineering students, but will be placed instead on subjects of broad general interest, in an attempt to induce the whole student body of G.W. to attend. There are several reasons for wanting to do this, among which I shall discuss only two.

First of all it has been my experience that the Engineering School is quite isolated from the University as a whole. After their freshman year engineering students really have quite limited contact with anybody other than engineering students. I can't help but feel that this is not a good status quo to maintain if the school hopes to produce truly educated people. For this reason, any program which would make it possible for students of engineering to hear and consider opinions held by people with completely different backgrounds would be invaluable to the educational experience of the student. Furthermore it is hoped that the program would serve to help eliminate or at least reduce the proverbial "communication gap" which is so pronounced today between the "lazy Columbian College student" and the "ignorant engineer".

As my second point I would like to mention that the type of topic which would interest the liberal minded student is really the sort of subject that the engineering student is in dire need of considering. I feel that the whole educational system at the Engineering School will have failed if its graduates can't talk sensibly about anything besides strictly technical matters. It would seem to me that the possibility of such a thing occurring, and it is possible now, would be most alarming to the student body and the faculty; yet, few people that I have talked with seem to be at all concerned about it. The seriousness of the problem is intensified when the very liberally conceived New Curriculum is considered: under

--Continued on page 15

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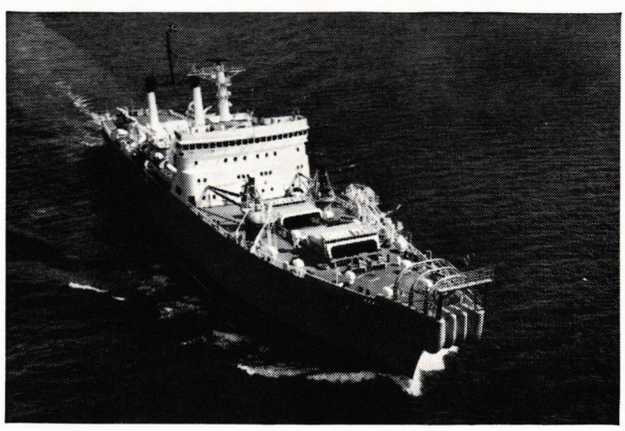

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ANALYTICAL DETERMINATION OF ELASTIC CONSTANTS FOR

by Douglas L. Jones

Probably the most basic mechanical property of any material is its reaction to applied forces. In 1687, Robert Hooke first promulgated a relation, the now famous Hooke's Law, which stated that the strain experienced by any body is directly proportional to the applied stress. This was essentially stating that there exist constants of proportionality between stress and strain. These constants of proportionality are universally called elastic constants or moduli of elasticity. In the most general case of an anisotropic elastic body there are 21 constants. However for an isotropic homogeneous body these reduce to two which are known as Lamé constants.

The greatest problem associated with the elastic constants is that, until recently, they had to be obtained empirically rather than analytically. As early as 1828, A. L. Cauchy and S. D. Poisson attempted analytical evaluations of these constants but were unsuccessful because of the complexity inherent in the problem. The problem then remained empirical in nature until the advent of quantum mechanics.

In the last forty years the advances in quantum mechanics have made possible the analytical evaluation of elastic constants for some of the simpler metallic structures. The application of the work of Schrodingar and his associates has permitted the evaluation of metallic energies from which the constants are obtained. It is the purpose of this paper to survey the recent advances which led to an analytical determination of the elastic constants.

Cohesive Energy Considerations

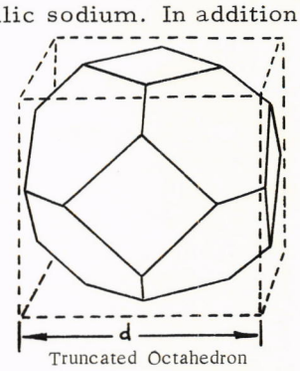
The current procedure utilized in calculating elastic constants is to first determine the cohesive energy of the metallic structure. The cohesive energy of a metal is defined as the energy required to dissociate a given mass of solid metal, at the absolute zero of temperature, into free atoms. In other words, it is the amount of heat which must be supplied to the metal, initially at $0^{o}K$, in order to vaporize it.

It is important to recognize and utilize the fact that solid metals have crystalline structure. That is, the nuclei of the atoms are arranged on a space or crystal lattice which extends regularly throughout the metal. Although crystal dislocations play an important role in regulating the properties of any real metal, the theory has not advanced to the extent where their effects can be included. The regularity of the lattice is of paramount importance in the evaluation of the cohesive energy from quantum mechanical considerations.

Even with the convenience of a regular lattice of nuclei the problem is much too formidable to be treated exactly. Considering that there are approximately 10^{23} nuclei per cubic centimeter and $Z \times 10^{23}$ electrons, it is clear that certain approximations must be utilized. (Here Z is the atomic number of the atom.) First of all, any magnetic interactions will be neglected since they are very much smaller than electrostatic interactions. Also the assumption that the vibrations of the nuclei are negligible may be made. This requires that the material be considered to be at the absolute zero of temperature. The most significant approximation, called the one electron approximation, assumes that all electrons except the valence electrons are tightly bound to the nucleus and can be treated as an integral part of it. This then reduces the problem to considering a regular crystal lattice of ion-cores surrounded by the valence electrons. For monovalent metals there will be one electron for each ion-core which also simplifies the calculations. Further approximations will be introduced later as they become necessary.

Utilizing all of the approximations mentioned above will, with some additional considerations, allow the evaluation of the cohesive energy to a reasonable degree of accuracy. This has been done for many metals but, since the cohesive energy is not of primary concern here, it will not be awarded much further detail.

In 1933, E. Wegner and F. Seitz made a significant contribution in considering the constitution of metallic sodium. In addition to introducing



Truncated Octahedron

OF THE

MONOVALENT METALS

Douglas L. Jones is a full-time graduate student working for a D.Sc. in Mechanics. This is his second year as NASA Predoctorial trainee. Three years ago, Doug was editor of Mecheleciv while finishing his undergraduate work here.

the one electron approximation, they also initiated another procedure which has fundamental importance. They introduced the idea of considering each nucleus as surrounded by a polyhedron which was constructed to fill the entire space of the lattice. If lines are drawn from the origin to all second nearest neighboring atoms and these lines bisected perpendicularly with planes, a unit polyhedron is constructed. (See Figure). Because of symmetry considerations the ground-state electron wave functions can be assumed to be zero on the surface of the unit polyhedron. This boundary condition is important in the evaluation of the cohesive energy. Now the metallic structure can be assumed to be composed of a regular array of ion-cores surrounded by a gas of electrons where properties of the electron wave function are known at the boundaries of the polyhendra. In the unstrained state the total charge due to the electron gas inside one unit polyhedron is equal to the unit electronic charge. It is also important to observe that the electronic wave function will be symmetric and extend periodically throughout the lattice.

In order to evaluate the wave functions of the valence electrons, Schrodinger's equation

$$H\psi_o = E\psi_o$$

is used, where H is the Hamiltonian operator of the crystal, is the ground state electronic wave function, and E is the electronic energy. Employing all of the approximations above allows the Hamiltonian to be written as

$$H = \sum_{i=1}^{N} \frac{\hbar^2}{2m} \nabla_i^2 + \sum_{a=1}^{N} \sum_{a=1}^{N} V_a(\vec{r}_i) + \frac{1}{2} \sum_{i \neq j}^{N} \sum^{N} \frac{e^2}{r_{ij}} + \sum_{a \neq b}^{N} \sum^{N} \frac{e^2}{R_{ab}}$$

where R_{ab} is the distance between nucleus a and nucleus b, r_{ij} is the distance between electron i and electron j, $\hbar$ is Planck's constant divided by 2π, m is the electronic mass, $V_a(\vec{r}_i)$ is the potential energy of electron i in the field of nucleus a, e the electronic unit of charge, and ∇_i^2 the Laplacian operator. This Hamiltonian operator has been further simplified by several ingenious schemes but they are too involved to be discussed here. Suffice it to say that it is possible to solve Schrodinger's equation for the wave function and hence the energy to a satisfactory degree of accuracy.

The Elastic Constants

Starting in 1935, K. Fuchs modified the previously outlined procedure so as to make the problem more amenable to solution. He reformulated the cohesive energy of the crystal to be composed of the following terms. (1) $W^{(o)}$ is the energy of the lowest electronic state in the field of the ion in each unit polyhedron. This includes the kinetic energy and part of the potential energy, namely, that part due to the interaction of an ion with its own electron. (2) $W^{(L)}$ is the rest of the potential energy. (3) $W^{(F)}$ is the Fermi energy of the valence electrons. (4) $W^{(I)}$ is the exchange energy which is defined as the interactions between the closed shells of the electrons.

If elastic distortions which change the shape of the unit cell, but leave the atomic volume unaltered are the only kind considered, the energies $W^{(o)}$ and $W^{(F)}$ will remain unchanged. For these dilatationless strains only the potential energy $W^{(L)}$ and the exchange energy $W^{(I)}$ need be considered. This is true for monovalent metals only since the Fermi energy does change for polyvalent metals.

Wegner and Seitz have shown that $W^{(L)}$ is equal to the difference between the energy, $W^{(1)}$, of a lattice with positive point charges +e embedded in a uniform negative charge distribution, and the energy $W^{(s)}$ of a spherical uniform negative charge distribution of radius r_o with a positive point charge +e at the center. $W^{(s)}$ depends upon the atomic volume only leaving $W^{(1)}$ to be evaluated. An extension of the method of Ewald for calculating the electrostatic energy, $W^{(1)}$, yields

$$W^{(\ell)} = \frac{e^2}{2} \left\{ \frac{1}{\pi\Omega} \sum_{\ell}^{i} \frac{\exp\left(-\frac{\pi^2}{E^2} h_\ell^2\right)}{h_\ell^2} + \sum_{\ell}^{i} \frac{1 - \phi(E R_\ell)}{R_\ell} - \frac{\pi}{E^2\Omega} - \frac{2E}{\sqrt{\pi}} \right\}$$

where $\phi(x) = \frac{2}{\sqrt{\pi}} \int_0^x \exp(-t^2)\, dt$

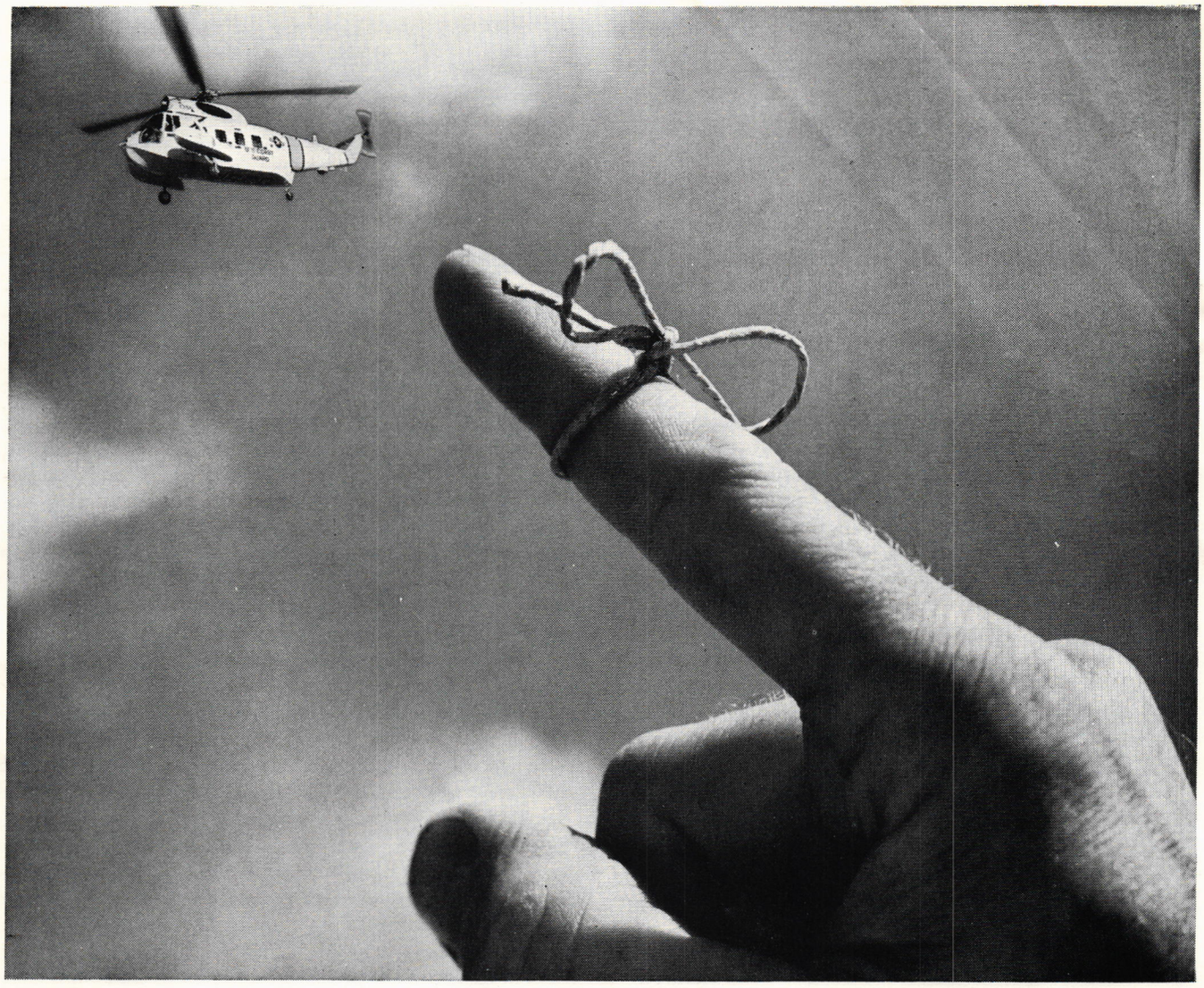
R_1 = magnitude of the lattice vector joining my two points of the lattice.

h_1 = magnitude of the reciprocal lattice vector.

Ω = atomic volume.

E = convergence factor having the dimensions of reciprocal length.

--Continued on page 15



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The OPEN FORUM—continued from page 10

this system (which I am completely in favor of) it is possible for someone to graduate with no credits at all in the so-called humanities; while on the other hand, if he is made to understand the importance of a liberal education, it can afford the student the heretofore denied opportunity to graduate as both a liberally educated and potentially prolific member of society. Therefore, it is hoped that this program will engender interest in a liberal education and hence enable the student to plan his curriculum in a manner which will yield as its end product both an engineer and a well educated individual.

The first OPEN FORUM will probably be held in October, and I would like to see the subject matter concern itself, in a general way, with the question of the Purpose of Education. I hope everybody will find it convenient to attend and offer any ideas or opinions that he might have.

ANALYTICAL DETERMINATION OF THE ELASTIC CONSTANTS, etc.—from page 12

The prime notation on the summation signs indicates that the origin of the coordinate system is to be excluded from consideration.

The exchange energy $W^{(I)}$ is composed of a van der Waals force of attraction and a repulsive force. The van der Waals force is negligible in comparison to the repulsive force which allows the exchange energy to be written as

$$W^{(I)} = D \exp\left(-\frac{r}{\rho}\right)$$

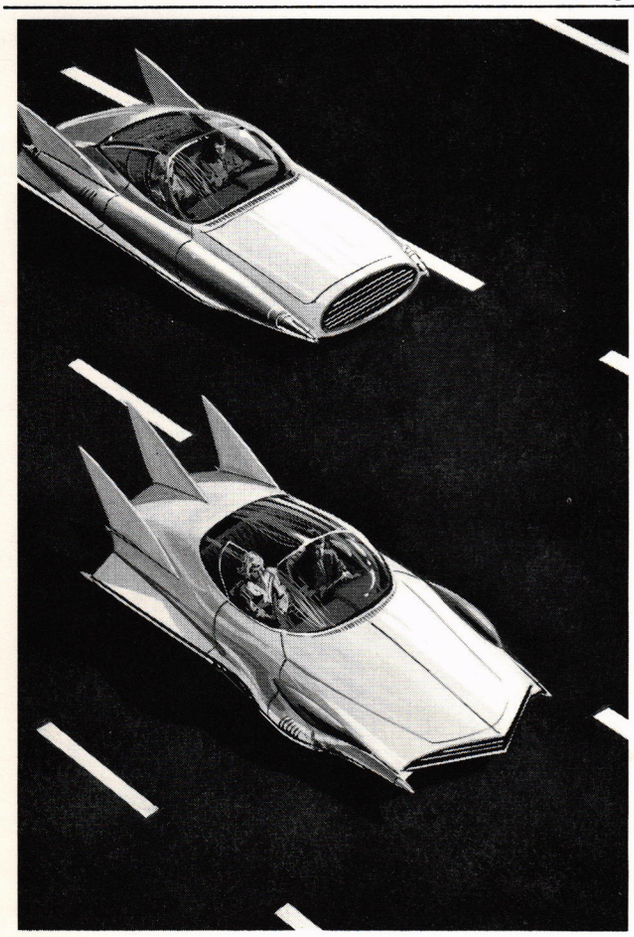
where D -- constant of the material

r -- distance between the ions

ρ -- constant depending upon the compressibility of the medium.

Now that the energy expressions have been obtained, they will be utilized in the determination of the elastic constants. What is most significant here is that the energy expressions must be written in terms of strains. This is necessary because the elastic constants are obtained by differentiating the energy expressions twice with respect to strain. The technique used here is identical to the strain-energy method employed in the theory of elasticity so it is not to be covered in detail here. Suffice it to say that the elastic constants are obtained by differentiation of the energy expressions twice with respect to strain.

More recently this approach has been expanded by several scientists. In 1951 an analysis by R. S. Leigh considered the Fermi energy in determining the shear constants for aluminum. J. Reitz and C. Smith contributed the elastic shear constants for magnesium and its alloys and, in 1961, B. J. Bernstein evaluated the shear constants for beryllium.



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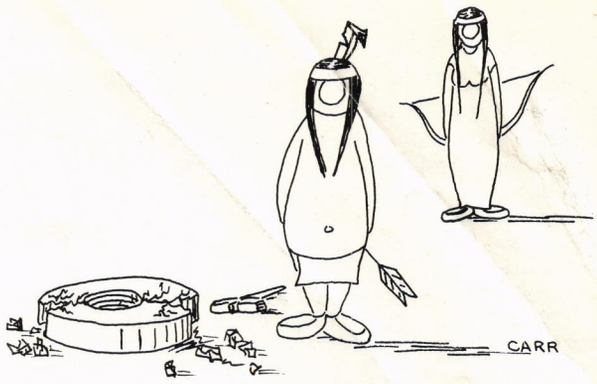

This is my slide rule,
There are many like it, but this one is mine.
My slide rule is my friend.
I will obey my slide rule,
And I shall learn to love it as a friend.
When it tels me that 5x5 is 23.8,
Then, by Damn, five times five is twenty-three point eight.
I will learn the anatomy of my slide rule,
Though I die in the struggle, I will use faithfully every scale.
The black scale and the red, the inverted C and the inside out log; the reversed A and the mutilated D.
I will master them all and they will serve me well, they will.
I will cherish my slipstick, and will treat it kindly;
I will call it my baby, and never shall profanity sear its long, graceful mahogany limbs.
My slide rule shall be my brother in suffering.
Through long hours of midnight toil we will work together, my slide rule and I.
And on the great date when my slide rule and I have finished our appointed task and the problem is done and answers are right,
I will take that damn stick, and have one hell of a fire,
I will.

* * *

"Not only is it proper to hold an engineer's hand in the dark, but it is usually necessary."

"You'll be poor and unhappy until you are forty," said the fortune teller to the engineer.

"And then what?" asked the engineer hopefully.

"You'll get used to it," answered the fortune teller.

* * *

The main advantage of being a nudist is that after you've been in for a swim you don't have to sit around in a wet bathing suit.

* * *

Who composed this sorority toast? "Here's to the land we love, and vice versa."

* * *

"Gee Mom," he complained, "None of the other guys are wearing lipstick!"

"Be quiet, stupid! We're almost at the draft board."

* * *

"But Henry, that isn't our baby."

"Shut up. It's a better carriage."

* * *

Customer (in hardware store): "Give me a plug."

Clerk: "Male or female?"

Customer: "Look, I just want to stop a leak. I don't plan on raising them."

* * *

The leader of the new White Muslim movement, now being organized will be known as Talcum X.

* * *

He drove his car with one hand and his girl friend wild with the other.

A man of German descent named Sexauer had borrowed some money from a small loan company and became delinquent in repaying it. Mr. Sexauer worked for a huge corporation which employed a big office staff composed of several comely secretaries. After allowing the debt to run for two months, the loan company sent an agent to see their debtor; and when the agent walked into the office, he asked, "Do you have a Sexauer here?"

"Sex-hour? Why we don't even have time for a coffee break."

* * *

They don't come any smarter than the guy who was able to talk his wife into being sorry for the girl who lost her hairpins in the back seat of his car.

* * *

A new father gazing unbelieving at a set of triplets that the nurse had just brought in from the delivery room finally quipped, "I'll take the one in the middle."

* * *

"Boy, am I scared! I got a letter from a man saying he'll shoot me if I don't stay away from his wife."

"Well, all you have to do is stay away from his wife."

"Oh yeah? He didn't sign his name!"

* * *

"I'm losing my punch," said the freshman as he hurriedly left the party.

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Back cover	General Electric Company

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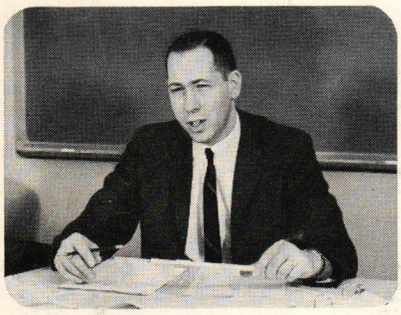
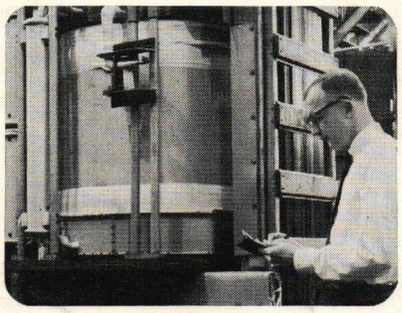
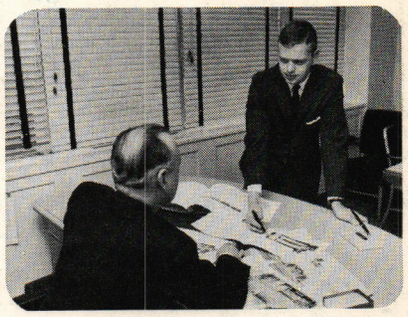


ELWOOD P. STROUPE, MSChE, PURDUE '62 is a design engineer at the Atomic Power Equipment Department. He has contributed to the design of Dresden 2's reactor—heart of the system. He'll follow it right through installation.



RONALD F. DESGROSEILLIERS, BSEE, U.S. MILITARY ACADEMY '60 is on the Manufacturing Training Program at G.E.'s Power Transformer Department. Ron is a production foreman helping build massive transformers for Dresden 2.



WORKING ON THE SALE of Dresden 2's turbine-generator is William J. Mahoney, BMS, Maine Maritime Academy, '56. After serving four years in the U.S. Navy, Bill joined the Technical Marketing Program to help G.E. meet its customer's needs.

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